$\omega_{10}=39$, $\omega_{11}=\omega_{12}=\omega_{13}=\omega_{14}=0$, $\omega_{20}=24$, $\omega_{21}=22$, $\omega_{22}=23$, $\omega_{23}=0$, and $\omega_{24}=0$. Hence, an optimal one-wafer cyclic schedule with cycle time $\Theta=109$ is obtained.

E. THE PRESENT INVENTION

[0137] The present invention is developed based on the theoretical development in Sections A-C above.

[0138] An aspect of the present invention is to provide a computer-implemented method for scheduling a tree-like multi-cluster tool to generate a one-wafer cyclic schedule. The multi-cluster tool comprises K single-cluster tools C_i's. The multi-cluster tool is decomposable into a plurality of CTCs each having a serial topology.

[0139] Exemplarily, the method makes use of the finding given by Theorem 1. In particular, the method comprises determining values of ω_{ij}, i=1, 2, . . . , K, and j=0, 1, . . . , n[i], such that (8)-(10) are satisfied for any pair of C_i and C_a, in which i, $a\in N_K$, C_a being an immediate downstream tool of C_i.

[0140] In determining the aforesaid values of ω_{ij}, preferably a CTC-Check algorithm for computing candidate values of ω_{ij} under a constraint on Θ. The computation of the candidate ω_{ij} values is performed for at least one individual CTC. The CTC-Check algorithm for CTC[f,l] is configured to compute the candidate ω_{ij} values such that $\omega_{i(n[i])}$ is minimized for each value of i selected from $N_{[f,l-1]}$. In one embodiment, the CTC-Check algorithm as used in the disclosed method is the one given by Section C.1.

[0141] Based on the CTC-Check algorithm, the values of ω_{ij}, i=1, 2, . . . , K, and j=0, 1, . . . , n[i], are determined as follows according to one embodiment of the present invention. First, the candidate values of ω_{ij} for the single-cluster tools in an individual CTC are determined by performing the CTC-Check algorithm under the constraint that Θ is equal to a lower bound of cycle time of the multi-cluster tool. This lower bound is a FP of a bottleneck tool among the K single-cluster tools, and is given by Π_h. If the candidate ω_{ij} values for the individual CTC are non-negative, then the candidate ω_{ij} values are set as the determined values of ω_{ij} for the individual CTC. If at least one of the candidate ω_{ij} values for the individual CTC is negative, a minimum cycle time for the individual CTC is first determined and then the values of ω_{ij} for the individual CTC are determined by performing the CTC-Check algorithm under a revised constraint that Θ is the determined minimum cycle time for the individual CTC.

[0142] More particularly, it is preferable and advantageous that the values of ω_{ij}, i=1, 2, . . . , K, and j=0, 1, . . . , n[i], are determined according to the procedure given in Section C.3, where the procedure is embodied in Algorithms 1 and 2 detailed above. A summary of this procedure is given as follows. First identify an L-CTC set consisting of first individual CTCs each having a leaf tool therein. It follows that one or more second individual CTCs not in the L-CTC set are also identified. For each of the first individual CTCs, a minimum cycle time is determined, followed by determining the values of ω_{ij} by performing the CTC-Check algorithm under the constraint that Θ is equal to the determined minimum cycle time. For each second individual CTC, candidate values of ω_{ij} for each single-cluster tool therein are determined by performing the CTC-Check algorithm under an initial constraint that Θ is equal to a maximum value of the minimum cycle times already determined for the first individual CTCs. If the candidate ω_{ij} values for the second individual CTC are non-negative, then the candidate ω_{ij} values are set as the determined values of ω_{ij} for the second individual CTC. If, on the other hand, at least one of the candidate ω_{ij} values for the second individual CTC is negative, then the following two-step procedure is performed. First, determine a minimum cycle time for the second individual CTC. Second, determine the values of ω_{ij} for the second individual CTC by performing the CTC-Check algorithm under a revised constraint that Θ is equal to the determined minimum cycle time for the second individual CTC.

[0143] The embodiments disclosed herein may be implemented using general purpose or specialized computing devices, computer processors, or electronic circuitries including but not limited to digital signal processors (DSP), application specific integrated circuits (ASIC), field programmable gate arrays (FPGA), and other programmable logic devices configured or programmed according to the teachings of the present disclosure. Computer instructions or software codes running in the general purpose or specialized computing devices, computer processors, or programmable logic devices can readily be prepared by practitioners skilled in the software or electronic art based on the teachings of the present disclosure.

[0144] In particular, the method disclosed herein can be implemented in a tree-like multi-cluster cluster tool if the multi-cluster tool includes one or more processors. The one or more processors are configured to execute a process of generating a one-wafer cyclic schedule according to one of the embodiments of the disclosed method.

[0145] The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A computer-implemented method for scheduling a tree-like multi-cluster tool to generate a one-wafer cyclic schedule, the multi-cluster tool comprising K single-cluster tools denoted as C_i, i=1, 2, . . . , K, the single-cluster tool C_i having a robot R_i for wafer handling, the multi-cluster tool being decomposable into a plurality of cluster-tool-chains (CTCs) each having a serial topology, an individual CTC consisting of single-cluster tools C_i, C_{i+1}, . . . $C_{i'}$ being denoted as CTC[i,i'], the method comprising:

determining values of ω_{ij}, i=1, 2, . . . , K, and j=0, 1, . . . , n[i], such that:

$$\theta_{lm}=\theta_{af}=\Theta,\ m\in\Omega_{n[l]} \text{ and } f\in\Omega_{n[a]};$$

$$\tau_{l(b[l,a])}\geq 4\lambda_a+3\mu_a+\omega_{a(n[a])}; \text{ and}$$

$$\tau_{a0}\geq 4\lambda_l+3\mu_l+\omega_{l(b[l,a]-1)};$$

are satisfied for any pair of C_l and C_a, in which l, $a\in N_K$, C_a being an immediate downstream tool of C_l;

wherein:

processing steps performed by C_i are indexed from 0 to n[i], an initial processing step of C_i having an index 0 and being a step of loading a wafer from a loadlock or a buffer module of C_i to R_i;